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SCHOOL OF AGRICULTURE

Agricultural Experiment Station

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STUDIES OF INHERITANCE

OF

EARLINESS IN CERTAIN AVENA CROSSES

(Technical Bulletin)

by C. F. Noll

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STUDIES OF INHERITANCE
OF
EARLINESS IN CERTAIN AVENA CROSSES

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF CORNELL UNIVERSITY FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

BY

CHARLES FRANKLIN NOLL

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STUDIES OF INHERITANCE OF EARLINESS IN CERTAIN AVENA CROSSES

By Charles F. Noll[1]

FORMER STUDIES OF INHERITANCE OF EARLINESS

It has been commonly accepted that differences in earliness in plants are conditioned by a series of factors and that these are similar to differences in size in mode of inheritance.

The only publication on inheritance of earliness in oats known to the writer is that of Caporn (4). He regarded his data for the F_1 and F_2 generations as not very dependable, but the F_1 was more or less intermediate and in the F_2 generation four plants out of 24 were green when the others were ripe. These late maturing plants gave late maturing F_3 populations. He concluded that earliness was Mendelian in inheritance and thought that probably three factors were involved in his cross. One parent was strong-tillering and the other weak, and in the hybrids he found the early plants weak-tillering and the late ones strong-tillering.

Since one might expect the inheritance of earliness in all plants to be similar, it is of interest to note what has been found in studies of earliness in other plants besides oats.

In corn, Hayes and East (10) believed that the F_1 hybrids matured earlier than the average date of maturity of the parents. They thought hybrid vigor caused an increase in rate of maturity.

Emerson and East (6) in corn crosses secured F_1 hybrids intermediate between the parents in earliness, and F_2 populations which had a range exceeding both parents. In F_3 they had pure types practically as early as the early parent but none quite so late as the late parent.

Hutcheson and Wolfe (13) compared, as to earliness, the F_1 hybrids of six crosses of corn with the parent varieties. One cross was earlier in tasseling and silking than the early parent and had a higher percentage of mature corn. The others were intermediate in earliness but, except in the case of one cross, were more nearly like the early parents than the late.

In cotton, Leake (16) found the F_1 generation uniformly intermediate in time of flowering. In the F_2 populations there was variation in time of flowering with the mode and the mean nearer the late parent.

Mendel (17) reported that with garden peas the time of flowering of the F_1 hybrids was almost exactly intermediate between those of the parents, but further results were not given.

Keeble and Pellow (15) from a cross between early and late garden peas concluded that lateness was dominant. The F_1 plants were earlier than the late parent but this was thought to be due to coupling (linkage) between thin stems, which were dominant to thick stems, and earliness.

In crosses of garden peas, Tschermak (19) secured F_1 plants intermediate in earliness, and in the F_2 families, plants varying from earlier than the early parent to later than the late parent. Some of the extremes bred true, but the intermediates gave offspring variable in time of flowering. His explanation was that two factors were involved.

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[1]Also presented to the Faculty of the Graduate School of Cornell University as a major thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

AUTHOR'S ACKNOWLEDGMENTS. The writer is greatly indebted to Dr. H. H. Love of Cornell University for suggestions and criticisms during the progress of these investigations, to the Department of Plant Breeding of Cornell University for material aid and equipment, and to R. D. Lewis for assistance in hybridizing and recording data.

Hoshina (12) in a cross of garden peas found the F_1 plants a little later than the early parent and the F_2 also intermediate but very variable. He secured some F_3 and F_4 families as constant in time of flowering as the parents.

From a cross between two varieties of rice differing in earliness, Hoshina (12) recovered pure early races like the early parent in earliness. He favored the multiple factor hypothesis and thought that in his cross the parents differed in three factors.

In crosses of tomatoes, Hayes and Jones (11) found early maturity associated with increase in production, and that crosses which did not show increase in earliness did not show increase in production.

In crosses of wheat, Biffen (2), Freeman (7), and Bryan and Pressley (3) found the F_1 plants intermediate in time of heading. In the F_2 and F_3 generations, some of Freeman's plants were later than the late parent, but none were earlier than the early parent. Bryan and Pressley recovered pure races which headed with the early parent and with the late parent and some which were intermediate.

Thompson (18), in wheat crosses, secured the parental types and some families which matured earlier than the early parents. He thought there were multiple factors concerned with earliness and that where the parents differed only slightly in earliness they differed by a number of factors.

Aamodt (1) crossed a spring and a winter variety of wheat and secured an F_2 population which when spring-sown began to head with the spring parent and continued heading for a period of eight weeks. There were also some plants which like the winter parent did not head. He recovered a homozygous family five weeks later than the spring parent. His results also indicated that the difference between the two varieties was due to a series of multiple factors.

OBJECT OF THE PRESENT STUDY

The object of the present study of inheritance of earliness in oats was to get more definite information concerning the factors responsible for earliness and especially to determine if they are alike in their effects and how many factors may be involved in certain crosses.

VARIETIES AND STRAINS CROSSED

The varieties or strains crossed are listed below; each one is given a number which is used to designate the variety or strain in the tables.

The seed was furnished by the Office of Cereal Investigations, United States Department of Agriculture, and by the Department of Plant Breeding of Cornell University. The seed from the Office of Cereal Investigations came in bulk, but that from Cornell was from individual plants. In most cases, seed was saved from each plant used in the crosses and sowed separately to determine its genetic purity and to compare it with the hybrids. From the behavior of the plant lines, all the parents used in the crosses here reported seemed pure for earliness.

Table 1. Varieties and strains crossed

No.	Name of variety or strain	Source of seed	Species[1]
1	Richland, C. I. 787	Office of Cereal Investigations	A.sativa
2	Albion, C. I. 729	Office of Cereal Investigations	A.sativa
3	Kherson, C. I. 134	Office of Cereal Investigations	A.sativa
4	Fulghum, C. I. 708	Office of Cereal Investigations	A.sterilis
5	Culberson, C. I. 273-1-10	Office of Cereal Investigations	A.sativa
7	Winter Turf, C. I. 274-20	Office of Cereal Investigations	A.sativa
8	Red Rustproof, C. I. 518-3	Office of Cereal Investigations	A.sterilis
9	Commercial Red Rustproof	Office of Cereal Investigations	A.sterilis
10	Red Texas	Cornell University	A.sterilis
12	Sixty Day	Cornell University	A.sativa
14	Awnless Propsteier	Cornell University	A.sativa
15	Twentieth Century	Cornell University	A.sativa
18	Black Winter	Cornell University	A.sativa
20	Turkish Rustproof No. 3	Cornell University	A.sterilis
21	Turkish Rustproof No. 4	Cornell University	A.sterilis

[1]This is according to the classification of W. C. Etheridge, Memoir 10, Cornell University Agricultural Experiment Station.

THE CROSSES STUDIED

The crosses here reported are listed below. Crosses involving different individuals of two different varieties were grown separately at first as were also the reciprocals of crosses. Since the parent varieties seemed homozygous and the reciprocals were alike, all the crosses made between two given varieties are combined in this study and considered as one cross.

Since many crosses were studied each was given a designation number for convenience in keeping the field records. These numbers are used in the tables, but the names of the varieties or strains are indicated in the headings.

Table 2. Crosses studied

Designation nos.	Varieties crossed	When grown			
		F_1	F_2	F_3	F_4
1X	Red Texas X Richland C. I. 787	'19	'20	'21	.....
2X	Richland C. I. 787 X Red Rustproof C. I. 518-3	'19	'20	'21	.....
5X	Albion C. I. 729 X Commercial Red Rustproof	'19	'20	'21	'22-'23-'24
10X	Kherson C. I. 134 X Black Winter	'19	'20	'21	'22-'23
14X	Fulghum C. I. 708 X Twentieth Century	'19	'20	'21	'22-'23
16X	Culberson C. I. 273-1-10 X Kherson C. I. 134	'19	'20	'21	.....
18X	Winter Turf C. I. 274-20 X Richland C. I. 787	'19	'20	'21	.....
22X	Red Rustproof C. I. 518-3 X Sixty-Day	'19	'20	....	.....
24X	Commercial Red Rustproof X Twentieth Century	'19	'20	'21	.....
39X	Black Winter X Sixty-Day	'19	'20	'21	.....
44X	Turkish Rustproof No. 3 X Sixty-Day	'19	'20	'21	'22-'23-'24
48X	Turkish Rustproof No. 4 X Sixty-Day	'19	'20	'21	'22-'23
49X	Kherson C. I. 134 X Commercial Red Rustproof	'20	'21	....	.....
50X	Red Rustproof C. I. 518-3 X Albion C. I. 729	'20	'21	....	.....
51X	Commercial Red Rustproof X Red Texas	'20	'21	....	.....
52X	Commercial Red Rustproof X Fulghum	'20	'21	....	.....
53X	Black Winter X Red Texas	'20	'21	....	.....
55X	Sixty-Day X Fulghum and Reciprocal	'21	'22	....	.....
57X	Commercial Red Rustproof X Kherson C. I. 134	'23	'24	....	.....
58X	Awnless Probsteier a X Fulghum C. I. 708	'23	'24	....	.....
60X	Sixty-Day X Twentieth Century	'23	'24	....	.....
61X	F_3 Fam. 96 (10X) X Kherson C. I. 134	'23	'24	....	.....
69X	Sixty-Day X Awnless Probsteier a	'24	....	....	.....
70X	Sixty-Day X Awnless Probsteier b	'24	....	....	.....
71X	Sixty-Day X Twentieth Century	'24	....	....	.....
72X	Awnless Probsteier b X Sixty-Day	'24	....	....	.....
73X	Twentieth Century X Kherson C. I. 134	'24	....	....	.....

The crosses numbered 1x to 48x, inclusive, were made in the field in 1919, and the F_1 plants and parents grown in a greenhouse at Cornell University in the winter of 1919-20. All subsequent generations of these crosses and all the generations of the other crosses were grown in the field. All crosses were compared with the parents in earliness.

HOW EARLINESS WAS DETERMINED

Earliness was based upon the date when the plant began to head. The date for a plant was the day on which the first spikelet of the earliest panicle came through the flag leaf. During the time of heading the plants were gone over every day or every two days and the plants marked as they headed with dated string tags. After an interval of one day in tagging, the plants which seemed to have headed the day before were so dated. There were some errors in dating when the tagging was not done every day, but these did not appreciably affect the distribution of the populations.

There were only a few F_1 plants of most crosses. For the F_2 populations all the seed was planted, and for the F_3 and F_4 populations the seed from the preceding generation was planted in four-foot plant-rows of 25 seeds each. The parents were planted likewise in rows of 25 seeds each or in two such rows each. It is thought now that the families in F_3 were too small and that there should have been more plants of the parents.

OBSERVATIONS ON HEADINGS OF OATS

There is a great deal of fluctuating variation in time of heading of oats, and the rate of development and time of heading are influenced by weather and soil conditions and by soil differences. Ideal conditions for such a study

Table 3. Correlation between mean date of heading of parent varieties and number of days of heading, 1920

		Days Required to Head																	
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
June	29	1	2	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..
	30	3	6	2	..	..	1	..	1	1	..	..	..	..	..	..	..	..	..
July	1	..	5	6	2	1	1	2	..	..	..	..	..	..	..	..	..	..	..
	2	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	1	..
	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	4	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	8	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..
	9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
	12	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
	13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	15	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	1
	16	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
	17	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	18	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	19	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	21	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
	22	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..
	23	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
	24	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
	25	..	..	..	..	..	1	..	..	..	..	..	1	1	1	..	..	..	1
	26	..	..	..	..	..	..	1	1	1	..	..	..	..	..	..	..	..	2
	27	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
	28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
	29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	31	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aug.	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	3	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..
	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	7	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
	11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	12	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
	13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	17	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	18	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	21	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1

$r = .54 \pm .05$.

would include uniform soil and unvarying conditions for growth throughout the growing season. This ideal, however, is practically unattainable.

Relation of the Time of Heading to the Length of the Heading Period

It was observed that the later varieties headed over a longer period than the earlier ones. The correlation between the time of heading and the length of the heading period is shown in Tables 3, 4, and 5. Not only did the later varieties as a rule require more days to complete their heading, but when the same varieties were planted at different dates the later planted lots headed as a rule over the longer period. This is shown in Table 6. It is not implied that these are rules which will always apply, for the rate of heading is influenced by other factors besides the length of day. The irregular heading of the late oats made it difficult to determine which late F_3 and F_4 families were homozygous.

Table 4. Correlation between mean date of heading of parent varieties of oats and number of days in heading, 1921

Duplicate rows listed separately

	Days Required to Head														
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
June 10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
15	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
16	...	...	2	...	1	...	...	...	...	...	...	...	...	...	...
17	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...
18	1	8	5	...	1	...	...	...	...	...	...	...	...	...	...
19	...	1	1	1	1	...	...	...	...	...	...	...	...	...	...
20	...	...	1	...	1	...	1	...	...	...	...	...	...	...	...
21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...
26	...	...	...	...	...	...	...	1	...	...	1	...	...	...	...
27	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...
28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	...	...	...	...	...	1	...	...	...	1	1	...	...	...	...
30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
July 1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
2	...	...	...	...	2	...	...	...	1	...	...	...	...	...	...
3	...	...	...	...	1	...	2	...	1	...	...	...	...	...	...
4	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
10	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
13	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...
14	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

$r = .65 \pm .05$.

Table 5. Correlation between mean date of heading of parent varieties of oats and number of days required to head, 1922

Data from rows on silt loam area

	Days Required to Head																	
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
June 15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
17	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
18	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20	4	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
21	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
24	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.	..	..	..
25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.	..	..	..
26	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.	..	..	..
27	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.	..	..	..
29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.	..	..	..
30	..	..	..	..	..	..	..	..	..	..	..	..	..	.	.	..	..	..
July 1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6	..	..	..	..	..	..	..	..	.	..	..	..	..	..	..	..	..	..
7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.	..	..	..
10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..
11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
17	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
18	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
21	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
24	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
26	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

$r = .94 \pm .02$.

Table 6. Influence of the time of planting and of heading upon the number of days required to head

		No. 13 Early Champion 1920		No. 15 Twentieth Century 1920		No. 2 Albion C. I. 729 1922		No. 3 Kherson C. I. 134 1922		F3 Fam. 96 1922		F3 Fam. 1116 1922	
Planted		5/13	5/25	5/13	5/25	5/1	5/13	5/1	5/13	5/1	5/13	5/1	5/13
June	18	....	....	....	....	2	....	....	....	....	....	....	....
	19	....	....	....	....	2	....	2	....	....	....	....	....
	20	....	....	....	....	10	....	10	....	....	....	....	....
	21	....	....	....	....	4	....	2	....	....	....	....	....
	22	....	....	....	....	4	....	5	....	4	....	....	....
	23	....	....	....	....	....	....	1	....	....	1	....	....
	24	....	....	....	....	....	....	1	....	4	....	....	....
	25	....	....	....	....	....	....	....	....	....	....	....	....
	26	....	....	....	....	....	2	....	....	5	....	....	....
	27	....	....	....	....	....	11	....	4	....	....	....	....
	28	10	....	....	....	....	2	....	6	2	3	2	....
	29	28	....	4	....	....	1	....	6	....	1	2	....
	30	8	....	26	....	....	5	....	....	....	8	1	....
July	1	2	....	13	....	....	....	....	1	....	....	2	....
	2	....	....	5	....	....	....	....	....	....	....	....	....
	3	....	....	....	....	....	....	....	....	....	1	....	....
	4	....	....	1	....	....	....	....	....	....	1	....	....
	5	....	....	2	....	....	....	....	....	....	....	5	....
	6	....	....	1	....	....	....	....	....	....	....	....	1
	7	....	....	....	....	....	....	....	....	....	....	....	1
	8	....	....	....	....	....	....	....	....	....	....	....	....
	9	....	....	....	....	....	....	....	....	....	2	....	2
	10	....	5	....	11	....	....	....	....	....	1	....	....
	11	....	7	....	14	....	....	....	....	....	....	....	....
	12	....	2	....	15	....	....	....	....	....	....	....	....
	13	....	3	....	17	....	....	....	....	....	....	....	1
	14	....	....	....	6	....	....	....	....	....	....	....	2
	15	....	2	....	3	....	....	....	....	....	....	....	1
	16	....	....	....	2	....	....	....	....	....	....	....	2
	17	....	1	....	1	....	....	....	....	....	....	....	1
	18	....	1	....	....	....	....	....	....	....	....	....	....
	19	....	....	....	....	....	....	....	....	....	....	....	....
	20	....	1	....	....	....	....	....	....	....	....	....	....

The Effect of Soil Differences

There were indications in 1921 that there were soil differences in the area on which the oats were grown which affected the time of heading, though the land on which they were grown comprised an area of only 40 feet by 200 feet and seemed uniform. In 1922, the soil on which the oats were planted was for the most part clay loam but there were two well defined areas which were more clayey. These areas were carefully marked in the planting plans so that it was known on which soil type every row was located, and the parent varieties were planted in duplicate on the two soil types.

The heading periods and the mean dates of heading for each variety are given in Table 8. Very consistently the oats headed later on the clayey area than on the clay loam. An apparent exception is the last variety listed in the table, Turkish Rustproof No. 4. However, of this strain only three plants headed on the clayey area, all the others dying August 15-30, without heading.

PHOTOPERIODISM IN OATS

The interesting investigations of Garner and Allard (8) on the influence of the relative length of day upon plants have shown that the time of flowering and fruiting in some plants is controlled by the length of day. They have re-

Table 7. Variation in time of heading 1922 due to soil differences

Parent strain	On clay loam		On clay	
	Heading period	Mean date	Heading period	Mean date
1. Richland C. I. 787	June 17–22	June 19	June 19–28	June 22
2. Albion, C. I. 729	June 18–22	June 20	June 18–26	June 22
8. Kherson, C. I. 134	June 19–24	June 20	June 20–25	June 22
4. Fulghum, C. I. 708	June 23–July 2	June 27	June 27–July 12	July 4
5. Culberson, C. I. 273-1-10	July 1–19	July 10	July 23 (1 plant)[1]	July 23
7. Winter Turf, C. I. 274-20	June 18–Aug. 1	July 26	July 22–Aug. 11	July 28
9. Commercial Red Rustproof	July 9–Aug. 1	July 13	July 8–18	July 14
12. Sixty-Day	June 18–22	June 20	June 21–26	June 24
15. Twentieth Century	June 16–22	June 19	June 20–28	June 23
18. Black Winter	July 2–14	July 8	July 4–15	July 12
20. Turkish Rustproof No. 3	June 19–26	June 21	June 20–29	June 25
21. Turkish Rustproof No. 4	July 31–Aug. 22[1]	Aug. 8	July 31–Aug. 15[1]	Aug. 6

[1]Some plants died Aug. 15-30 without heading.

Intervals Between Dates of Heading Are Not the Same Every Year

The difference in time of heading of unlike varieties is not the same every year. Differences between the mean dates of heading of the parents in three different crosses for the years 1920 to 1924 are given in Table 8. The shortest intervals for all three pairs of varieties were in 1921.

Table 8. Differences in time of heading of parent varieties in different years

Mean dates of heading

Cross 5X

Year	Albion C. I. 729 X	Commercial Red Rustproof	Difference
1920	June 30	July 22	22 days
1921	June 18	June 29	11 days
1922	June 20	July 13	23 days
1922 (Clayey Area)	June 22	July 14	22 days
1923	June 24	July 11	17 days
1924	July 5		

Cross 10X

	Kherson C. I. 134 X	Black Winter	
1920	July 1	July 28	27 days
1921	June 19	June 25	6 days
1922	June 20	July 8	18 days
1922 (Clayey Area)	June 22	July 12	20 days
1923	June 26	July 10	14 days
1924	July 7		

Cross 14X

	Fulghum X	Twentieth Century	
1920	July 12	July 1	11 days
1921	June 20	June 18	2 days
1922	June 27	June 19	8 days
1922 (Clayey Area)	July 4	June 23	11 days
1923	June 30	June 25	5 days
1924	July 14	July 5	9 days

ported one small scale test, Garner and Allard (9), on the effect of prolonging the illumination period on oats, wheat, barley and rye, using a spring and a winter variety of each. With oats, the lengthening of the day to midnight by the use of electric light shortened the vegetative period of the spring variety by 77 days and of the winter variety by only 45 days. With each of the other grains, also, the forcing action of the electric light was much greater with the spring than with the winter variety. The authors state the following conclusion: "It appears that a fundamental distinction between the winter and the spring types as such rests on the rapidity with which the latter respond to the increasing day length of spring."

Wanzer (20), working with winter wheat, reached the conclusion that the winter habit of wheat was due to the absence of the critical stimulus which was essential for the initiation of the jointing stage. He thinks a winter wheat has a photoperiod for jointing and one for heading, the latter requiring longer days than the former.

Cooper (5) found the spring habit of wheat dominant to the winter habit. The length of day in late summer was not great enough for the heading of the winter types when spring-sown, but when the duration of light was increased in September by the use of electric lights two-thirds of the winter types soon headed.

These studies just referred to, on the influence of the length of day on heading (photoperiodism), are related to the present investigations of the inheritance of earliness in oats, since some of the crosses are between spring varieties and winter varieties, or varieties successfully grown further south as winter varieties. Photoperiodism is probably responsible for the irregular heading of the late varieties and for the failure of some plants of the latest varieties and of crosses with them to head at all. However, it seems as though in most if not all of the crosses here reported the length of time required for vegetative growth is the controlling influence in determining the time of heading.

EXPERIMENTAL RESULTS

The F_1 Generations

The F_1 plants of the crosses made in 1919 were grown in a greenhouse at Cornell University during the winter of 1919-20. As a rule two plants were grown in a five-inch pot. These were planted October 11.

The dates of heading of these F_1 plants and the parents are given in Table 9 and shown graphically in Diagram 1. The conditions in the greenhouse were very favorable but there was a lack of uniformity in temperature in different parts of the bed and this doubtless affected the rate of development. With most of the varieties the heading extended over long periods, though in the field as a rule each headed within a week to ten days. It is thought that these data show only roughly the relative earliness of the F_1 generations with respect to the parents but it is significant that in most of the crosses the hybrids are earlier or as early as the early parents; and in these apparent exceptions (the last three listed) while the differences between the mean dates of heading of the parents are 66, 66, and 67 days, respectively, the means of the F_1 populations are only 11, 13, and 9 days later than the means of the early parents, respectively.

Of 11 other crosses the F_1 plants were grown with the parents in the field. The dates of heading are reported in Tables 10, 11, 12, and 13. Here the F_1 generations headed with the early parents or earlier; and in cross 51X (Table 10) the parents headed together, but the F_1 plant headed 15 days earlier than the earliest parent plants.

It was mentioned before that Hayes and East (9) believed that hybrid vigor caused an increase in rate of development in F_1 crosses of corn. It is quite possible that hybrid vigor in these F_1 oat hybrids induced somewhat more rapid development and earlier heading, but the data secured in the other generations indicate that this does not adequately explain the increase in earliness.

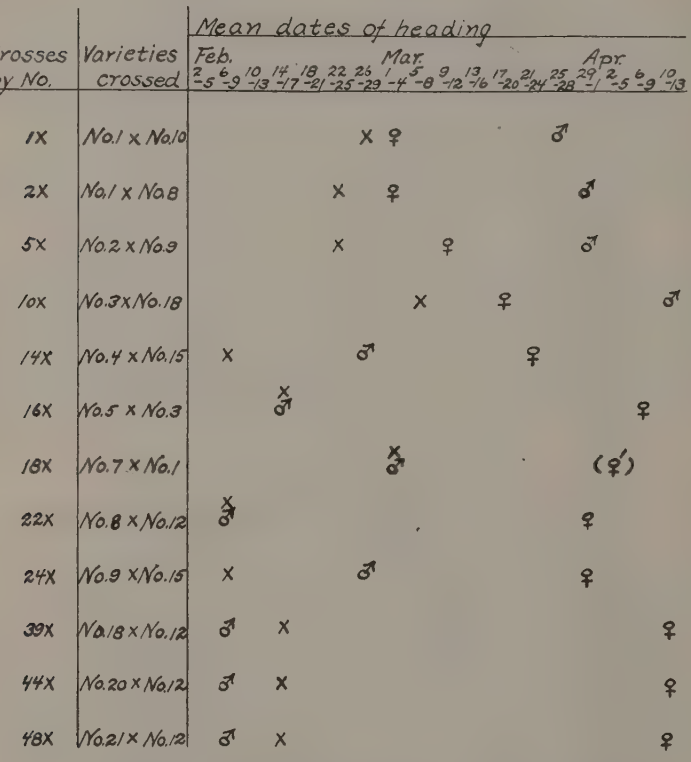
Table 9. Dates of heading of F_1 plants and parents in greenhouse 1919-20; planted October 11, 1919

Crosses	Dates of heading								
	Pistillate parent.			Pollen parent			F_1 plants		
	No. plants	Range	Mean	No. plants	Range	Mean	No. plants	Range	Mean
1X, Richland X Red Texas	17	2/19–3/19	3/4.12±1.20	14	3/18–4/6	3/24.71±1.12	18	2/17–3/12	2/26.44±1.24[1]
2X, Richland X Red Rustproof	17	2/19–3/19	3/4.12±1.20	12	2/25–4/10	3/29.83± .87	6	2/18–3/1	2/24.50±1.12
5X, Albion X Comm. Red Rustproof	10	2/18–4/5	3/8.80±3.45	6	3/18–4/12	3/29.00±2.84	8	2/16–3/2	2/24.25±1.06
10X, Kherson X Black Winter	24	2/28–4/1	3/16.79±1.45	8	4/5–4/18	4/10.88±1.29	9	2/27–3/15	3/8.22±1.35
14X, Fulghum X Twentieth Century	14	3/9–3/30	3/22.07± .34	6	2/24–3/2	2/26.33± .69	2	2/8	2/8.00± 00
16X, Culberson X Kherson	5	4/2–4/12	4/6.20± .98	24	2/28–4/1	3/16.79±1.45	2	3/16–3/17	3/16.50± .24
18X, Winter Turf X Richland	.....	.....	.....[2]	17	2/19–3/19	3/4.12±1.20	2	3/1–3/5	3/3.00± .95
22X, Red Rustproof X Sixty-Day	12	3/25–4/10	3/29.83± .87	12	1/27–3/3	2/6.17±2.57	3	2/4–2/9	2/7.33±1.00
24X, Commercial Red Rustproof X Twentieth Century	6	3/18–4/12	3/29.00±2.94	6	2/24–3/2	2/26.33± .69	3	2/3–2/9	2/5.67±1.00
39X, Black Winter X Sixty-Day	8	4/5–4/18	4/10.88±1.29	12	1/27–3/3	2/6.17±2.57	3	2/8–2/22	2/16.67±2.41
44X, Turkish Rustproof No. 3 X Sixty-Day	7	4/5–4/20	4/12.14±1.32	12	1/27–3/3	2/6.17±2.57	10	2/11–2/24	2/18.90± .82
48X, Turkish Rustproof No. 4 X Sixty-Day	4	4/7–4/19	4/12.75±1.66	12	1/27–3/3	2/6.17±2.67	2	2/14–2/17	2/15.50± .72

[1]The means computed from the observed dates of heading. The F_1 plants of cross IX headed from Feb. 17 to Mar. 12 and the computed mean was Feb. 26.44, with a probable error of ±1.24 days.

[2]Winter Turf not grown in the greenhouse 1919–20. In the field in 1920-22 this variety was 38, 25 and 37 days later, respectively, than Richland.

Diagram 1. Mean dates of heading of F_1 and parent varieties in greenhouse 1920. Planted Oct. 11, 1919.


Mean dates of heading
Crosses by No.
Varieties crossed
Feb.
Mar.
Apr.
2-5 6-9 10-13 14-17 18-21 22-25 26-29 1-4 5-8 9-12 13-16 17-20 21-24 25-28 29-1 2-5 6-9 10-13
1X No.1 x No.10
2X No.1 x No.8
5X No.2 x No.9
10X No.3 x No.18
14X No.4 x No.15
16X No.5 x No.3
18X No.7 x No.1
22X No.8 x No.12
24X No.9 x No.15
39X No.18 x No.12
44X No.20 x No.12
48X No.21 x No.12

[1] Pistillate parent in cross 18X not grown. In the field much later than the pollen parent.

Table 10. Dates of heading of F_1 plants and parents planted in the field at Ithaca, N. Y., May 12, 1920

	49X			50X			51X			52X			53X		
	Kherson	Commercial Red Rustproof	F_1	Red Rustproof	Albion	F_1	Commercial Red Rustproof	Red Texas	F_1	Commercial Red Rustproof	Fulghum	F_1	Black Winter	Red Texas	F_1
June 27	....	.....	..	.....	....	1	.....	....	..	.....	....	..	.....	....	..
28	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
29	1	.....	..	.....	7	1	.....	....	..	.....	....	..	.....	....	..
30	8	.....	..	.....	3	..	.....	....	..	.....	....	..	.....	....	..
July 1	2	.....	1	.....	1	..	.....	....	..	.....	....	..	.....	....	..
2	1	.....	..	.....	1	..	.....	....	..	.....	1	..	.....	....	..
3	1	.....	..	.....	....	..	.....	....	1	.....	1	..	.....	....	..
4	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
5	....	.....	1	.....	....	..	.....	....	..	.....	....	..	.....	....	..
6	....	.....	..	.....	1	..	.....	....	..	.....	2	..	.....	....	..
7	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
8	....	.....	..	.....	....	..	.....	....	..	.....	1	..	.....	....	..
9	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
10	....	.....	..	.....	....	..	.....	....	..	.....	1	..	.....	....	..
11	....	.....	..	.....	....	..	.....	....	..	.....	1	..	.....	....	..
12	....	.....	..	.....	....	..	.....	....	..	.....	....	1	.....	....	..
13	....	.....	..	.....	....	..	.....	....	..	.....	2	..	.....	....	..
14	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
15	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
16	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
17	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
18	....	1	..	.....	....	..	1	6	..	1	....	..	2	1	..
19	....	.....	..	.....	....	..	.....	1	..	.....	....	..	.....	....	..
20	....	1	..	.....	....	..	1	....	..	1	....	..	.....	....	2
21	....	1	..	.....	....	..	1	3	..	1	....	..	.....	....	..
22	....	2	..	.....	....	..	2	1	..	2	....	..	.....	....	..
23	....	4	..	.....	....	..	4	5	..	4	....	..	2	3	..
24	....	5	..	.....	....	..	5	6	..	5	....	..	1	1	..
25	....	4	..	.....	....	..	4	8	..	4	....	..	.....	....	..
26	....	4	..	.....	....	..	4	4	..	4	....	..	.....	....	..
27	....	.....	..	.....	....	..	.....	2	..	.....	....	..	1	....	..
28	....	1	..	.....	....	..	1	4	..	1	....	..	.....	....	..
29	....	1	..	3	....	..	1	....	..	1	....	..	.....	1	..
30	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
31	....	3	..	2	....	..	3	....	..	3	....	..	.....	....	..
Aug. 1	....	2	..	.....	....	..	2	....	..	2	....	..	.....	....	..
2	....	.....	..	1	....	..	.....	....	..	.....	....	..	.....	....	..
3	....	.....	..	.....	....	..	.....	1	..	.....	....	..	.....	....	..
4	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
5	....	.....	..	1	....	..	.....	....	..	.....	....	..	.....	....	..
6	....	.....	..	1	....	..	.....	....	..	.....	....	..	.....	....	..
7	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
8	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
9	....	.....	..	.....	....	..	.....	....	..	.....	....	..	.....	....	..
10	....	.....	..	.....	....	..	.....	....	..	.....	....	..	1	....	..

Table 11. Dates of heading of F_1 plants and parents planted in the field at State College, Pa., April 20, 1921

	55X		
	Sixty-Day	Fulghum	F_1
June 9	....	....	....
10	....	....	....
11	....	....	....
12	....	....	....
13	....	....	1
14	....	....	....
15	....	....	1
16	3	....	....
17	11	....	1
18	12	12	....
19	26	....	....
20	8	2	....
21	2	1	....
22	1	....	....
23	....	2	....
24	....	1	....
25	....	....	....
26	....	1	....

The F_2 Generations

Since the F_1 plants headed with the early parents or earlier it was to have been expected that the F_2 generations would range in time of heading from the early parent to the late parent or from earlier than the early parent to later than the late parent and, in either case, with the majority of the plants, early.

F_2 generations of 22 crosses were grown and the heading periods of these in comparison with those of the parents are given in Tables 14 to 17. The most noticeable fact is that the majority of these F_2 families (17 in fact) began to head earlier than the early parents, the earliest plants in these crosses being from 3 to 16 days earlier than the earliest plants of the respective early parents.

The heading of the F_2 generations and parents is given in Tables 14 to 17.

The heading in F_1 and F_2 may be summarized as follows:

In ten crosses the F_1 plants headed earlier than the early parents or a little later (in crosses 39X, 44X and 48X), and the F_2 families began heading earlier than the early parent.

In four crosses the F_1 plants headed with the early parents, and the F_2 families began to head with the early parents.

In seven crosses the F_1 plants headed with the early parents, but the F_2 families began to head appreciably earlier than the early parents.

In one cross (10X), the F_1 plants were earlier than the early parent, the difference in the means being 8.57 ± 1.98 days (Table 9), but the F_2 family began heading only one day earlier than the early parent. Here one should have expected some plants much earlier than the early parent. That these earliest F_2 plants were potentially earlier than the early parent and that, because of fluctuating variation, they had not headed earlier is proved by the fact that

Table 12. Dates of heading of F_1 plants and parents planted in the field at State College, Pa., April 1, 1923

		57X			58X			60X			61X		
		Commercial Red Rustproof	Kherson	F_1	Awnless Probsteier	Fulghum	F_1	Sixty-Day	Twentieth Century	F_1	F_3 Fam. 96	Kherson	F_1
June	19	.....	....	..	.....	....	..	....	.....	..	.....	....	..
	20	.....	....	..	.....	....	..	....	.....	..	1	....	..
	21	.....	....	..	.....	....	..	....	.....	..	.....	....	1
	22	.....	....	..	.....	....	2	4	1	..	.....	....	..
	23	.....	1	..	.....	1	4	44	24	..	1	1	..
	24	.....	12	..	.....	3	1	41	17	..	17	12	..
	25	.....	27	2	.....	6	..	25	13	..	43	27	..
	26	.....	16	..	.....	8	..	6	9	1	86	16	..
	27	.....	6	..	.....	8	..	2	1	..	43	6	..
	28	.....	10	..	.....	5	..	....	1	..	7	10	..
	29	.....	....	..	.....	4	..	....	1	..	.....	....	..
	30	.....	1	..	.....	10	..	....	4	..	.....	1	..
July	1	.....	....	..	.....	4	..	....	.....	..	4	....	..
	2	.....	1	..	.....	8	..	....	.....	..	4	1	..
	3	.....	1	..	.....	2	..	....	.....	..	.....	1	..
	4	.....	....	..	2	5	..	....	.....	..	1	....	..
	5	.....	1	..	3	5	..	....	.....	..	.....	1	..
	6	.....	....	..	4	1	..	....	.....	..	.....	....	..
	7	.....	....	..	3	....	..	....	.....	..	.....	....	..
	8	.....	....	..	2	2	..	....	.....	..	.....	....	..
	9	3	....	..	.....	3	..	....	.....	..	.....	....	..
	10	4	....	..	.....	1	..	....	.....	..	.....	....	..
	11	19	....	..	1	....	..	....	.....	..	.....	....	..
	12	15	....	..	3	1	..	....	.....	..	.....	....	..
	13	2	....	..	.....	....	..	....	.....	..	.....	....	..
	14	1	....	..	.....	1	..	....	.....	..	.....	....	..

from two of these early plants there were grown two homozygous F_3 families (Nos. 45 and 48), which were distinctly earlier than the early parent. See Table 22, p. 30.

In all the larger F_2 populations, the distribution according to time of heading gives a skew curve with the mode near the beginning of the heading period.

Of the 17 families which began heading earlier than the early parents, only eight had plants later than the latest of the respective late parents. With sufficiently large numbers one could expect every F_2 family, which began heading earlier than the early parent, to have some plants later than those of the late parent.

Table 13. Heading of F_1 plants and parents planted in the field at State College, Pa., May 7, 1924

		69X		
		Sixty-Day	Awnless Probsteier	F1
July	1	....	....	....
	2	1	....	....
	3	5	....	1
	4	21	....	13
	5	10	....	3
	6	5	....	1
	7	1	....	1
	8	1	....	....
	9	2	....	....
	10	1	....	....
	11	....	....	....
	12	....	....	....
	13	....	....	....
	14	....	....	....
	15	....	....	....
	16	....	....	....
	17	....	....	....
	18	....	....	....
	19	....	2	....
	20	....	9	....
	21	....	10	....
	22	....	12	....
	23	....	4	....
	24	....	3	....
	25	....	....	....

Table 14. Dates of heading of F_2 families and parents, 1920

Parents: No. 1, Richland; No. 2, Albion; No. 3, Kherson; No. 4, Fulghum; No. 5, Culberson; No. 8, Red Rustproof; C. I. 518-3; No. 9, Commercial Red Rustproof; No. 10, Red Texas; No. 15, Twentieth Century; No. 18, Black Winter.

		Parents										F_2 Families					
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 8	No. 9	No. 10	No. 15	No. 18	1X 1x10	2X 1x8	4X 2x9	10X 3x18	14X 4x15	16X 5x8
June	20	...	...	...	...	...	...	...	...	...	...	...	1	1	...	2	...
	21	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...
	22	...	...	...	...	...	...	...	...	...	...	3	2	3	...	6	...
	23	...	...	...	...	...	...	...	...	...	...	8	3	1	...	3	...
	24	...	...	...	...	...	...	...	...	...	...	14	5	13	...	6	...
	25	...	...	...	...	...	...	...	...	...	...	17	5	4	...	5	...
	26	...	...	...	...	...	...	...	...	...	...	39	18	14	...	9	...
	27	...	...	...	...	...	...	...	...	...	...	50	30	21	2	13	1
	28	1	...	1	...	...	...	...	...	...	...	57	25	6	3	12	...
	29	25	7	20	1	...	...	...	...	4	...	105	62	14	10	22	1
	30	30	12	66	...	...	...	...	...	26	...	74	43	12	19	7	4
July	1	18	6	28	...	...	...	...	...	26	...	47	38	7	11	7	1
	2	4	1	20	4	...	...	...	...	13	...	26	21	2	5	5	2
	3	1	...	10	4	...	...	...	...	5	...	29	22	9	28	4	2
	4	1	...	3	1	...	...	...	...	...	...	15	10	3	7	4	...
	5	1	...	...	4	...	...	...	...	1	...	25	11	2	11	3	...
	6	...	1	3	5	...	...	...	...	2	...	20	14	3	13	4	2
	7	...	...	...	1	...	...	...	...	...	...	18	6	...	11	2	6
	8	...	...	1	6	...	...	...	...	...	...	35	32	1	25	3	3
	9	...	...	...	2	...	...	...	...	...	...	7	7	3	1	2	...
	10	...	...	1	6	...	...	...	...	...	...	13	11	1	16	2	...
	11	...	...	...	8	...	...	...	...	...	...	12	9	1	5	2	...
	12	...	...	...	5	...	...	...	...	...	2	10	12	...	20	2	4
	13	...	...	...	7	...	...	...	...	...	1	8	6	...	2	2	1
	14	...	...	...	1	3	...	...	...	...	1	8	4	1	7	...	1
	15	...	...	...	...	1	...	...	...	...	1	11	6	...	6	...	1
	16	...	...	...	3	3	...	...	...	...	...	4	5	2	3	...	1
	17	...	...	...	2	1	...	...	...	...	1	2	3	...	1	...	...
	18	...	...	...	...	1	...	1	6	...	4	2	6	...	3	...	1
	19	...	...	...	2	3	...	3	1	...	1	7	...	...	1	1	...
	20	...	...	...	...	1	...	4	...	...	4	3	2	1	3	2	...
	21	...	...	...	1	5	...	6	3	...	...	1	...	...	1	...	...
	22	...	...	...	...	3	1	2	1	...	3	3	5	...	4	3	...
	23	...	...	...	3	2	1	10	5	...	7	5	5	1	1	1	...
	24	...	...	...	...	4	1	8	6	...	5	3	3	...	2	...	1
	25	...	...	...	1	...	1	7	8	...	5	1	2	...	2	...	...
	26	...	...	...	2	2	3	4	5	...	2	...	1	...	1	1	...
	27	...	...	...	1	2	...	...	2	...	1	6	...	1	3	...	...
	28	...	...	...	...	3	2	1	4	...	4	...	2	...	3	...	...
	29	...	...	...	2	...	3	4	1	...	1	...	5	...	1	...	...
	30	...	...	...	...	1	...	...	...	...	2	...	1	...	1	...	1
	31	...	...	...	...	1	2	3	...	...	3	3	2	...	1	...	...
Aug.	1	...	...	...	...	2	...	2	...	...	...	1	...	...	1	...	...
	2	...	...	...	...	1	2	...	1	...	...	2	...	...	...	...	...
	3	...	...	...	...	...	...	...	1	...	2	1	...	...	...	...	...
	4	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...
	5	...	...	...	...	1	...	...	...	...	...	1	1	...	...	1	...
	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	7	...	...	...	...	1	...	...	...	...	...	...	...	...	1	1	...
	8	...	...	...	...	2	...	...	...	...	...	...	...	...	2	...	...
	9	...	...	...	...	1	...	...	...	...	...	...	1	...	...	...	...
	10	...	...	...	...	...	...	...	...	...	1	1	1	...	1	...	...
	11	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...
	12	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...
	13	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...
	14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	15	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	16	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	...

Table 15. Dates of heading of F_2 families and parents, 1920

Parents: No. 1, Richland; No. 7, Winter Turf; No. 8, Red Rustproof, C. I. 518-3; No. 9, Commercial Red Rustproof; No. 12, Sixty-Day; No. 15, Twentieth Century; No. 18, Black Winter; No. 20, Turkish Rustproof No. 8; No. 21, Turkish Rustproof No. 4.

		Parents								F_2 families					
		No. 1	No. 7	No. 8	No. 9	No. 12	No. 15	No. 18	No. 20	No. 21	18X 7x1	22X 8x12	24X 9x15	39X 18x12	44X 20x12	48X 21x12
June	18	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
	19	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	20	...	...	...	...	...	...	...	...	...	...	4	1	...	...	...
	21	...	...	...	...	...	...	...	...	...	...	5	4	...	4	...
	22	...	...	...	...	...	...	...	...	...	...	7	7	...	8	...
	23	...	...	...	...	...	...	...	...	...	...	9	5	...	13	...
	24	...	...	...	...	...	...	...	...	...	...	9	5	1	20	1
	25	...	...	...	...	...	...	...	...	...	...	8	13	...	17	...
	26	...	...	...	...	...	...	...	2	...	...	12	18	3	31	2
	27	...	...	...	...	...	...	...	8	..	..	14	14	2	27	1
	28	1	...	...	...	...	...	...	15	...	...	14	9	2	50	10
	29	25	...	...	...	10	4	...	17	...	...	17	28	6	47	6
	30	30	...	...	...	32	26	...	8	...	1	12	13	7	47	8
July	1	18	...	...	...	10	26	...	3	...	...	17	14	9	36	12
	2	4	...	...	...	9	13	...	3	...	...	4	3	5	16	5
	3	1	...	...	...	5	5	...	2	...	...	3	1	3	9	5
	4	1	...	...	...	...	...	...	...	...	1	3	3	6	18	4
	5	1	...	...	...	4	1	...	1	...	1	2	1	7	16	4
	6	...	...	...	...	1	2	...	4	...	...	3	3	4	14	2
	7	...	...	...	...	1	...	...	...	...	1	5	2	2	11	1
	8	...	...	...	...	...	...	...	2	...	...	5	3	9	17	4
	9	...	...	...	...	...	...	...	...	...	...	2	2	1	4	...
	10	...	...	...	...	...	...	...	...	...	1	2	1	6	2	...
	11	...	...	...	...	...	...	...	...	...	1	2	9	6	5	1
	12	...	...	...	...	...	...	2	...	...	1	2	2	4	2	...
	13	...	...	...	...	...	...	1	...	...	...	1	2	5	5	1
	14	...	...	...	...	...	...	1	...	...	...	2	2	3	5	2
	15	...	...	...	...	...	...	1	...	...	1	6	2	1	2	...
	16	...	...	...	...	...	...	...	1	...	...	2	3	1	3	2
	17	...	...	...	...	...	...	1	...	...	...	2	1	...	4	...
	18	...	...	...	1	...	...	4	...	...	...	1	...	...	3	...
	19	...	...	...	3	...	...	1	...	...	1	1	1	...	8	1
	20	...	...	...	4	...	...	4	...	...	1	1	1	...	8	1
	21	...	...	...	6	...	...	...	...	...	...	2	5	...	1	3
	22	...	...	1	2	...	...	3	...	...	...	1	1	...	3	1
	23	...	...	1	10	...	...	7	...	...	...	...	2	...	4	...
	24	...	...	1	8	...	...	5	...	...	...	...	4	1	1	1
	25	...	...	1	7	...	...	5	...	...	...	1	1	...	1	...
	26	...	...	3	4	...	...	2	...	...	2	1	...	1	...	...
	27	...	...	...	...	...	...	1	...	...	...	...	...	1	2	...
	28	...	...	2	1	...	...	4	...	...	1	...	...	2	.	1
	29	...	...	3	4	...	...	1	...	...	...	3	...	...	1	...
	30	...	2	...	...	...	...	2	...	...	1	...	...	...	...	...
	31	...	...	2	3	...	...	3	...	...	1	...	...	1	2	1
Aug.	1	...	4	...	2	...	...	...	...	...	...	...	1	...	2	...
	2	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...
	3	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...
	4	...	1	...	...	...	...	...	...	...	...	...	...	1	...	1
	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	6	...	1	...	...	...	...	...	...	1	...	...	...	...	2	...
	7	...	7	...	...	...	...	...	...	3	...	...	...	...	...	...
	8	...	3	...	...	...	...	...	...	1	...	...	...	...	...	...
	9	...	4	...	...	...	...	...	...	1	...	...	...	...	...	...
	10	...	3	...	...	...	...	1	...	...	...	...	...	...	...	...
	11	...	2	...	...	...	...	2	...	...	...	...	...	...	...	...
	12	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...
	13	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...
	14	...	3	...	...	...	...	...	...	3	...	...	...	...	...	...
	15	...	3	...	...	...	...	1	...	4	...	...	...	...	...	...
	16	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...
	17	...	...	...	...	...	...	...	...	5	...	...	...	...	...	...
	18	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...
	19	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	21	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	23	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	26	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	28	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
	29	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sept.	1	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...
	2	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...
	3	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	6	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
	7	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...
Did not head		...	...	...	...	...	...	...	...	9	...	...	...	...	...	9

Table 16. Dates of heading of F_2 families and parents, 1921

Parents: No. 2, Albion; No. 3, Kherson; No. 4, Fulghum; No. 8, Red Rustproof, C. I. 518-3; No. 9, Commercial Red Rustproof; No. 10, Red Texas; No. 18, Black Winter.

		Parents							F2 Families				
		No. 2	No. 3	No. 4	No. 8	No. 9	No. 10	No. 18	49X 3x9	50X 8x2	51X 9x10	52X 9x4	53X 18x10
June	12	....	....	....	....	....	....	....	....	3	....	....	....
	13	....	....	....	....	....	....	....	5	23	5	....	....
	14	....	....	....	....	....	....	....	....	5	3	....	....
	15	....	....	....	....	....	....	....	1	13	7	....	....
	16	....	....	....	....	....	....	....	2	6	12	....	....
	17	1	....	....	....	....	....	....	10	10	4	3	2
	18	15	17	14	....	....	....	....	5	10	6	10	7
	19	....	....	....	....	....	....	....	1	1	....	....	1
	20	3	3	4	....	....	....	....	....	....	....	2	5
	21	13	1	16	....	....	....	....	10	4	2	7	6
	22	....	....	....	....	....	....	....	....	....	1	....	1
	23	3	....	....	....	....	....	....	1	....	....	....	2
	24	1	....	3	....	....	....	....	1	1	1	....	7
	25	....	....	....	....	1	....	....	....	....	2	2	3
	26	....	....	1	....	2	....	3	....	1	....	3	1
	27	....	....	....	....	2	....	1	2	....	....	....	6
	28	....	....	....	....	....	....	....	....	....	....	....	....
	29	....	....	....	1	4	12	....	....	....	....	1	....
	30	....	....	....	....	....	....	2	....	1	2	2	7
July	1	....	....	....	....	....	....	....	....	....	....	....	....
	2	....	....	....	12	6	32	....	....	....	....	....	....
	3	....	....	....	1	....	2	....	....	....	....	....	1
	4	....	....	....	....	....	....	....	....	....	....	....	1
	5	....	....	....	5	....	14	....	....	....	....	5	....
	6	....	....	....	....	....	....	....	....	....	....	....	....
	7	....	....	....	....	....	6	1	....	....	....	1	2
	8	....	....	....	....	....	....	....	....	....	....	....	....
	9	....	....	....	....	....	2	....	....	....	....	....	1
	10	....	....	....	....	....	....	....	....	....	....	....	....
	11	....	....	....	....	....	....	....	....	....	....	....	....
	12	....	....	....	....	....	....	....	....	....	....	....	1
	13	....	....	....	....	....	....	....	....	....	....	....	....
	14	....	....	....	....	....	....	1	....	....	....	....	2
	15	....	....	....	....	....	....	....	....	....	....	....	....
	16	....	....	....	....	....	....	....	....	....	....	....	1
	17	....	....	....	....	....	....	....	....	....	....	....	1
	18	....	....	....	....	....	....	....	....	....	....	....	....
	19	....	....	....	....	....	....	....	....	....	....	....	1
	20	....	....	....	....	....	....	....	....	....	....	....	1
	21	....	....	....	....	....	....	....	....	....	....	....	....
	22	....	....	....	....	....	....	....	....	....	....	....	1
	23	....	....	....	....	....	....	....	....	....	....	....	1
	24	....	....	....	....	....	....	....	....	....	....	....	1
	25	....	....	....	....	....	....	....	....	....	....	....	1

Table 17. Dates of heading of F_2 families and parents in 1922 and 1924

Parents: No. 3, Kherson; No. 4, Fulghum; No. 5, Culberson; No. 9, Commercial Red Rustproof; No. 12, Sixty-Day; No. 14, Awnless Probsteier.

1922				1924											
	Parents		F_2 Family		Parents							F_2 Families			
	No. 4	No. 12	55X 12 x 4		No. 3	No. 4	No. 9	No. 12	No. 14	No. 15	F_3 Fam. 96	57X 9 x 3	58X 14 x 4	60X 12 x 15	61X Fam. 96 x 3
June 8	....	....	....	July 1	....	....	....	....	....	....	....	....	....	....	....
9	....	....	1	2	....	....	....	....	....	....	....	....	....	....	....
10	....	....	....	3	....	....	....	....	....	....	....	....	2	....	....
11	....	....	....	4	....	....	....	....	....	....	....	....	1	....	2
12	....	....	2	5	....	....	....	....	....	....	....	....	3	....	6
13	....	....	3	6	....	....	....	....	....	....	....	....	9	....	7
14	....	....	1	7	....	....	....	....	....	6	....	1	12	3	3
15	....	....	6	8	....	....	....	2	....	17	....	4	19	5	3
16	....	....	13	9	....	....	....	11	....	9	....	6	19	12	2
17	....	....	15	10	5	2	3	16	....	7	....	14	29	12	2
18	....	1	12	11	7	4	1	3	....	....	4	7	21	9	3
19	....	5	16	12	14	10	5	6	....	....	6	3	20	9	4
20	1	11	16	13	5	1	4	1	....	....	6	3	23	6	2
21	....	3	1	14	7	13	4	....	....	....	3	....	14	4	....
22	....	2	9	15	1	1	4	....	....	1	3	2	19	3	....
23	1	....	4	16	....	3	4	....	....	....	3	....	9	5	....
24	1	....	3	17	1	3	1	....	....	....	3	1	10	4	....
25	1	....	7	18	....	....	2	....	....	....	1	....	1	....	....
26	....	....	....	19	1	....	....	....	....	....	....	....	3	1	....
27	3	....	5	20	....	....	1	....	....	....	1	....	....	1	....
28	....	....	2	21	....	1	1	....	....	....	1	....	5	....	....
29	5	....	1	22	....	....	1	....	1	....	....	....	3	....	....
30	....	....	2	23	....	....	1	....	....	....	....	....	2	....	....
July 1	....	....	....	24	....	1	....	....	1	....	....	....	....	....	....
2	1	....	1	25	....	....	....	....	2	....	....	....	....	....	....
3	....	....	....	26	....	....	1	....	2	....	....	....	....	....	....
4	....	....	....	27	....	....	....	....	5	....	....	....	....	....	....
5	....	....	1	28	....	....	....	....	4	....	....	....	....	....	....
6	....	....	....	29	....	....	....	....	3	....	....	....	....	....	....
7	....	....	....	30	....	....	....	....	1	....	....	....	....	....	....
8	....	....	....	31	....	....	....	....	2	....	....	....	....	....	....
9	....	....	....		....	....	....	....	....	....	....	....	....	....	....
10	....	....	....		....	....	....	....	....	....	....	....	....	....	....
11	....	....	....		....	....	....	....	....	....	....	....	....	....	....
12	....	....	....		....	....	....	....	....	....	....	....	....	....	....
13	....	....	....		....	....	....	....	....	....	....	....	....	....	....
14	....	....	....		....	....	....	....	....	....	....	....	....	....	....

THE HYPOTHESIS

In these crosses earliness is dominant to lateness and both the F_1 and the F_2 data support the hypothesis that the time of heading is dependent upon a series of multiple factors which together have a cumulative effect. These conclusions are further supported by the fact that homozygous races earlier than the early parents were secured in three different crosses. These will be discussed in more detail later.

If the above holds true generally, then two varieties of oats may differ genetically for earliness in one of two ways as follows:

1. One parent may have one or more dominants of which the other has the recessive allelomorphs. Thus the genotype of one parent may be represented as AABB and of the other as aabb.

Crosses between such parents would give an F_1 population like the early parent in time of heading and an F_2 population in which the heading ranged from the early to the late parent.

Such a relationship of parents seems to have existed in crosses 16X, 18X, 52X, 60X, and 69X. (See Tables 9 to 13 for the heading in F_1 and Tables 14 to 17 for the heading in F_2).

2. Each parent may have one or more dominants which the other lacks. Thus the genotype of one parent may be represented as AABBcc and of the other as aabbCC. Such a cross should give an F_1 population earlier than either parent and an F_2 population ranging in heading from earlier than either parent to later than either.

The parents might be alike in time of heading and contain different dominant factors for earliness.

Most of the crosses included in this study seemed to have such a relationship of parents, for in most of them the F_1 was earlier than the early parent and the F_2 began heading much earlier than the early parent. In some crosses in which the F_2 began heading earlier than the earlier parent, there were no plants later than the late parents. However, the expected proportion of the population later than the late parent in such crosses would be small. For example, if three factors having the same effect are involved and the parents are AABBcc and aabbCC, only 1.6 per cent of the F_2 population should be later than the late parent. In a cross between such parents as AABBCCdd and aabbccDD with the factors having the same quantitative effect, only .4 per cent could be expected to be later than the late parent. (See Table 18, p. 24).

In one cross: namely, 51X, the parents headed together but the F_1 headed much earlier than the parents, and in the F_2 generation 41 out of a total of 45 plants were earlier than the earliest plant of the parents. (See Tables 10 and 17).

In cross 44X, the parents headed two months apart in the greenhouse (see Table 9) but together in the field. (See Table 25). The F_1 generation was a trifle later than the early parent in the greenhouse, but the F_2 (grown in the field) began heading much earlier than the parents. In this cross there must be one or more factors which cause unlike rate of development under different conditions.

Table 18. How with multiple factors each dominant to its recessive allelomorph and together having a cumulative effect the F_2 families would be grouped according to earliness.

Factors involved	No. of dominants in each group	No. of plants in each group according to earliness		Per cent in each group
2	2	1 x 9 = 9		56.3
	1	2 x 3 = 6		37.5
	0	1 x 1 = 1		6.3
		16		
3	3	1 x 27 = 27		42.2
	2	3 x 9 = 27		42.2
	1	3 x 3 = 9		14.1
	0	1 x 1 = 1		1.6
		64		
4	4	1 x 81 = 81		31.7
	3	4 x 27 = 108		42.2
	2	6 x 9 = 54		21.1
	1	4 x 3 = 12		4.7
	0	1 x 1 = 1		.4
		256		
5	5	1 x 243 = 243		23.7
	4	5 x 81 = 405		39.6
	3	10 x 27 = 270		26.4
	2	10 x 9 = 90		8.8
	1	5 x 3 = 15		1.5
	0	1 x 1 = 1		.1
		1024		
6	6	1 x 729 = 729		17.8
	5	6 x 243 = 1458		35.6
	4	15 x 81 = 1215		29.6
	3	20 x 27 = 540		13.2
	2	15 x 9 = 135		3.3
	1	6 x 3 = 18		.4
	0	1 x 1 = 1		.02
		4096		
7	7	1 x 2187 = 2187		13.3
	6	7 x 729 = 5103		31.1
	5	21 x 243 = 5103		31.1
	4	35 x 81 = 2835		17.3
	3	35 x 27 = 945		5.7
	2	21 x 9 = 189		1.2
	1	7 x 3 = 21		.13
	0	1 x 1 = 1		.006
		16384		

HOMOZYGOUS RACES RECOVERED

To secure homozygous races, F_2 generations were grown of 11 crosses and F_4 generations from selected F_3 families of five crosses. For both of these generations there were grown plant-rows in which 25 grains had been planted. The F_3 populations were too small and the F_4 generations were necessary to prove whether or not the F_3 families which headed in a short period were homozygous. A race was considered homozygous if there was no segregation when plant-rows were grown from the F_3 family.

Tha dates of heading of the F_2 generations and of the homozygous races recovered in comparison with the parents are given in Tables 19 to 28. A glance at these will show that some were earlier than the early parent, some like the early parent, some intermediate between the parents, and one later than the parents (in cross 44X).

Table 19. Dates of heading of parents and homozygous races from cross 4X
Parents: No. 2, Albion; No. 9, Commercial Red Rustproof. The mean dates are indicated by#.

	1920		1921				1922						1923				1924			
	Parents		Parents		F3 Families			Parents On clay loam		On clay		F4 from F3 Families		On clay	Parents		F4 from F2 Families			Parents		F4 from F3 Families	
	No. 2	No. 9	F2	No. 2	No. 9	1049	1052	1058	No. 2	No. 9	No. 2	No. 9	1049	1052	1058	No. 2	No. 9	1049	1052	1058	No. 2	No. 9	1049	1058
June 8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	...	...	...	...	...	5	...	...	...	...	...	...	9	...	...	...	...	...	...	...	...	...	...	...
10	...	...	...	...	...	11	...	8	...	...	...	...	48	...	1	...	...	...	...	...	...	...	...	...
11	...	...	...	...	...	3#	...	2#	...	...	...	...	54	3	8	...	...	...	...	...	...	...	...	...
12	...	...	...	...	...	2	8	9	...	...	...	...	50	8	23	...	...	...	...	...	...	...	...	...
13	...	...	...	...	...	1	16#	4	...	...	...	...	56	13	25	...	...	...	...	...	...	...	...	...
14	...	...	...	...	...	2	...	...	...	...	...	...	39#	36	45	...	...	...	...	...	...	...	...	...
15	...	...	...	...	...	...	...	...	...	...	...	...	77	53	59	...	...	3	...	...	...	...	...	...
16	...	...	...	...	...	...	...	...	...	...	...	...	86	127#	105#	...	...	17	1	...	...	...	...	...
17	...	...	...	3	...	...	...	...	...	...	...	...	48	159	103	...	...	50	3	9	...	...	...	...
18	...	...	...	12	...	...	...	...	2	...	1	...	11	14	30	...	...	135	10	49	...	...	...	...
19	...	...	...	#	...	...	...	...	2	...	...	...	11	20	26	...	...	102#	60	83	...	...	...	...
20	...	...	1	9	...	...	...	...	10#	...	2	...	1	8	4	...	...	67	172#	125#	...	...	...	...
21	...	...	...	...	...	...	...	...	4	...	7	...	1	1	...	...	...	28	75	43	...	...	...	...
22	...	...	2	...	...	...	...	...	4	...	1#	...	3	2	1	3	...	10	40	14	...	...	...	...
23	...	...	...	...	...	...	...	...	...	...	1	...	...	2	...	22	...	4	5	8	...	...	...	...
24	...	...	2	...	...	...	...	...	...	...	3	...	...	1	...	20#	...	2	5	4	...	...	2	...
25	...	...	4	...	1	...	...	...	...	...	1	...	...	...	...	19	...	2	4	...	...	...	10	...
26	...	...	20	...	2	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	9#	...
27	...	...	19	...	2	...	...	...	...	...	...	...	...	1	...	...	...	2	...	...	...	...	8	2
28	...	...	14	...	...	...	...	...	...	...	...	...	...	...	...	1	...	1	...	...	...	...	9	2
29	...	...	32	...	4#	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7
30	9#	...	33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	6#
July 1	5	...	17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4
2	...	...	9	...	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
3	...	...	7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...
4	...	...	7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	...	...	1
5	...	...	9	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	10	...	...	...
6	...	...	10	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	8#	...	...	...
7	...	...	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	...	...	...

Table 19. Dates of heading of parents and homozygous races from cross 4X—Continued
Parents: No. 2, Albion; No. 9, Commercial Red Rustproof. The mean dates are indicated by#.

	1920			1921					1922						1923				1924			
	Parents			Parents		F3 Families			Parents On clay loam		On clay		F4 from F3 Families		On clay	Parents		F4 from F3 Families			Parents		F4 from F3 Families	
	No. 2	No. 9	F2	No. 2	No. 9	1049	1052	1058	No. 2	No. 9	No. 2	No. 9	1049	1052	1058	No. 2	No. 9	1049	1052	1058	No. 2	No. 9	1049	1058
July 8	...	...	11	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	4	...	...	1
9	...	...	3	...	...	...	...	...	...	2	...	2	...	...	...	...	3	...	...	...	...	...	...	...
10	...	...	6	...	...	...	...	...	...	4	...	...	...	...	...	...	4	...	...	...	...	3	...	...
11	...	....	4	...	...	...	...	...	...	...	...	...	...	...	...	...	19#	...	...	...	...	1	...	...
12	...	...	4	...	...	...	...	...	...	1	...	1	...	...	...	...	15	...	...	...	...	5	...	...
13	...	...	...	...	...	...	...	...	...	6	...	2	...	...	...	...	2	...	...	...	...	4	...	...
14	...	...	3	...	...	...	...	...	...	#	...	4#	...	...	...	...	1	...	...	...	...	4	...	...
15	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4#	...	...
16	...	...	3	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...	...	...	...	4	...	...
17	...	...	6	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	1	...	...
18	...	...	3	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	2	...	...
19	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
21	...	3#	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
23	...	3	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
24	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
27	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	...	...	2	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Aug. 1	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Table 20. Mean dates of heading of parents and homozygous races from cross 4X

Parents: No. 2, Albion, C. I. 729; No. 9, Commercial Red Rustproof.

Year	Parents		Homozygous Races		
	No. 2	No. 9	1049	1052	1058
1921	6/18.63± .19	6/29.27± .44	6/10.54± .13	6/12.67± .06	6/11.30± .16
1922 on clay loam	6/20.27± .16	7/13.87±1.14	6/13.89± .08	6/16.29± .06	.....
1922 on clay	6/21.88± .23	7/13.53± .57	.....	.....	6/15.75± .06
1923	6/24.27± .18	7/11.27± .10	6/18.81± .05	6/20.31± .04	6/19.71± .05
1924	7/ 5.77± .14	7/15.09± .45	6/26.47± .15	.....	6/30.04± .31

Table 21. Dates of heading of parents, the F_2 generation and homozygous races of cross 10X Parents: No. 3, Kherson C. I. 134; No. 18, Black Winter. The mean dates are indicated by#.

	1920			1921							1922								1923								1924		
	Parents			Parents		F_3 Families					Parents On clay loam		On clay		F_4 from F_3 Families				Parents		F_4 from F_3 Families				Parent	F_4 from F_3 Families		
	No. 3	No. 18	F_2	No. 3	No. 18	45	48	96	80		No. 3	No. 18	No. 3	No. 18	45	48	96	80	No. 3	No. 18	45	48	96	80	No. 3	45	96	
June 11	...	....	..	...	....	...	...	...	...		...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...	
12	...	....	..	...	....	12	6	...	...		...	....	...	....	1	...	On	...	...	....	...	...	...	...	.....	...	...	
13	...	....	..	...	....	7#	12#	...	...		...	....	...	....	5	1	clay	...	...	....	...	...	...	...	.....	...	...	
14	...	....	..	...	....	...	5	...	...		...	....	...	....	7	1	...	...	...	....	...	...	...	...	.....	...	...	
15	...	....	..	1	....	1	...	...	...		...	....	...	....	15	1	...	...	...	....	...	...	...	...	.....	...	...	
16	...	....	..	2	....	1	...	...	...		...	....	...	....	59	4	...	...	...	....	...	...	...	...	.....	...	...	
17	...	....	..	7#	....	...	...	1	...		...	....	...	....	114	29	...	...	...	....	3	...	...	...	.....	...	...	
18	...	....	..	9	....	...	...	8	3		...	....	...	....	54#	64	...	...	...	....	12	1	...	...	.....	...	...	
19	...	....	..	2	....	...	...	3#	2		2	....	...	....	61	71	1	...	...	....	21	3	...	...	.....	...	...	
20	...	....	..	...	....	...	...	10	3#		10	....	3	....	35	95#	3	...	...	....	58	19	1	...	.....	...	...	
21	...	....	..	...	2	...	...	...	6		2#	....	1	....	2	23	5	...	...	....	50#	71	...	...	.....	...	...	
22	...	....	..	...	1	...	...	...	...		5	....	3#	....	4	41	13	...	...	....	33	67#	...	...	.....	...	...	
23	...	....	..	...	4	...	...	...	...		1	....	4	....	1	5	5	...	...	....	14	38	1	...	.....	...	...	
24	...	....	..	...	2	...	...	...	...		1	....	1	....	...	9	12	...	12	....	13	19	17	...	.....	...	...	
25	...	....	..	...	#	...	...	...	...		...	....	1	....	1	...	46	...	15#	....	2	8	43	1	.....	...	...	
26	...	....	..	...	4	...	...	...	...		...	....	...	....	1	10	44	2	11	....	1	2	86#	8	.....	...	...	
27	...	....	2	...	...	...	...	...	...		...	....	...	....	...	1	47#	8	4	....	...	...	43	21	.....	5	...	
28	1	....	3	...	1	...	...	...	...		...	....	...	....	...	1	89	103	3	....	...	2	7	18	.....	...	...	
29	20	....	10	...	4	...	...	...	...		...	....	...	....	...	...	53	9	...	....	...	...	...	11	.....	7	...	
30	66	....	19	...	....	...	...	...	...		...	....	...	....	...	...	7	14#	...	....	...	...	...	18	.....	#	...	
July 1	28#	....	11	...	....	...	...	...	...		...	....	...	....	...	...	...	8	...	....	...	...	4	15#	.....	3	...	
2	20	....	5	...	....	...	...	...	...		...	2	...	....	...	...	5	7	...	....	...	...	4	28	.....	3	...	
3	10	....	28	...	....	...	...	...	...		...	....	...	....	...	...	1	31	...	....	...	...	...	7	.....	...	...	
4	3	....	7	...	....	...	...	...	...		...	....	...	1	...	...	...	5	...	3	...	...	1	11	.....	1	...	
5	...	....	11	...	....	...	...	...	...		...	4	...	....	...	...	...	5	...	....	...	...	...	7	.....	...	...	
6	3	....	13	...	....	...	...	...	...		...	1	...	....	...	...	1	...	...	1	...	...	...	7	.....	1	...	
7	...	....	11	...	....	...	...	...	...		...	....	...	....	...	...	...	...	...	3	...	...	...	6	.....	...	...	
8	1	....	25	...	....	...	...	...	...		...	#	...	1	...	...	1	...	...	3	...	...	...	3	.....	...	...	
9	...	....	11	...	....	...	...	...	...		...	....	...	....	...	...	...	1	...	6	...	...	...	4	1	...	...	
10	1	....	16	...	....	...	...	...	...		...	6	...	....	...	...	1	...	...	3	...	...	...	...	18	...	...	
11	...	....	5	...	....	...	...	...	...		...	....	...	2	...	...	...	...	...	2#	...	...	...	1	5	...	6	
12	...	2	20	...	....	...	...	...	...		...	....	...	1#	...	...	...	...	...	8	...	...	...	2	3#	...	10	
13	...	2	2	...	....	...	...	...	...		...	3	...	1	...	...	...	...	...	1	...	...	...	...	8	...	34	

Table 21. Dates of heading of parents, the F_2 generation and homozygous races of cross 10X—Continued
Parents: No. 3, Kherson C. I. 134; No. 18, Black Winter. The mean dates are indicated by#.

	1920			1921					1922							1923					1924		
	Parents			Parents		F_3 Families			Parents On clay loam		On clay		F_4 from F_3 Families				Parents		F_4 from F_3 Families				Parent	F_4 from F_3 Families	
	No. 3	No. 18	F_2	No. 3	No. 18	45	48	96	80	No. 3	No. 18	No. 3	No. 18	45	48	96	80	No. 3	No. 18	45	48	96	80	No. 3	45	96
July 14	...	1	7	...	....	...	...	...	...	...	1	1	4	...	...	...	...	...	4	...	...	...	...	2	...	32
15	...	1	6	...	....	...	...	...	...	...	....	...	2	...	...	1	...	...	....	...	...	...	...	6	...	28#
16	...	....	3	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	1	...	13
17	...	1	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	14
18	...	4	3	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	5
19	...	1	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	2
20	...	4	3	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	4
21	...	....	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	1
22	...	3	4	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	1	...	...	...	...	.....	...	1
23	...	7	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	2
24	...	5	2	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
25	...	5#	2	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	1
26	...	2	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
27	...	1	3	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	1	...	...	...	...	.....	...	...
28	...	4	3	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
29	...	1	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
30	...	2	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
31	...	3	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
Aug. 1	...	....	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
2	...	....	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
3	...	2	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
4	...	....	2	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
5	...	....	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
6	...	....	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
7	...	....	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
8	...	....	2	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
9	...	....	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
10	...	1	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
11	...	2	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
12	...	....	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
13	...	....	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
14	...	....	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
15	...	1	..	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...
16	...	....	1	...	....	...	...	...	...	...	....	...	....	...	...	...	...	...	....	...	...	...	...	.....	...	...

Table 22. Mean dates of heading of parents and homozygous races from cross 10X
Parents: No. 3, Kherson, C. I. 134; No. 18, Black Winter.

Year	Parents		Homozygous Races			
	No. 3	No. 18	45	48	96	80
1921	6/17.43± .14	6/25.11± .44	6/12.67± .16	6/12.96± .10	6/19.00± .15	6/19.86± .22
1922 on clay loam	6/20.81± .19	7/ 8.41± .62	6/17.55± .06	6/19.75± .07	.....	6/29.60± .05
1922 on clay	6/22.15± .28	7/12.08± .61	.....	.....	6/26.95± .09	.....
1923	6/25.36± .12	7/10.92± .50	6/20.83± .08	6/21.99± .06	6/26.11± .07	7/ 1.21± .19
1924	7/11.73± .19	.....	6/29.82± .35	.....	7/14.80± .17	.....

Table 23. Dates of heading of parents, the F_2 generation and homozygous races from cross 14X Parents: No. 4, Fulghum, C. I. 708; No. 15, Twentieth Century. The mean dates are indicated by#.

	1920			1921				1922				1923				1924		
	Parents			Parents		F_3 Families		Parents		F_4 from F_3 Families		Parents		F_4 from F_3 Families		Parent	F_4 from F_3 Families	
	No. 4	No. 15	F_2	No. 4	No. 15	1084	1105	No. 4	No. 15	1084	1105	No. 4	No. 15	1084	1105	No. 15	1084	1105
June 8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	2	.....	.....	.....	.....	.....	.....	.....
10	.....	.....	.....	.....	.....	.....	6	.....	.....	8	2	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	8	2	.....	.....	24	11	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	.....	.....	4#	5	.....	.....	29	52	.....	.....	.....	.....	.....	.....	.....
13	.....	.....	.....	.....	.....	7	2	.....	.....	22	29	.....	.....	.....	.....	.....	.....	.....
14	.....	.....	.....	.....	.....	3	1#	.....	.....	38	55	.....	.....	.....	.....	.....	.....	.....
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	74	86#	.....	.....	1	.....	.....	.....	.....
16	.....	.....	.....	.....	.....	.....	2	.....	1	69#	96	.....	.....	17	4	.....	.....	.....
17	.....	.....	.....	.....	6	.....	2	.....	2	107	69	.....	.....	46	19	.....	.....	.....
18	.....	.....	.....	12	6#	.....	1	.....	3	15	20	.....	.....	49	55	.....	.....	.....
19	.....	.....	.....	.....	7	.....	.....	.....	9	37	17	.....	.....	50#	66	.....	.....	.....
20	.....	.....	2	2#	3	.....	1	1	4	6	3	.....	.....	81	67#	.....	.....	.....
21	.....	.....	.....	1	.....	.....	.....	.....	.....	1	.....	.....	.....	33	54	.....	.....	.....
22	.....	.....	6	.....	.....	.....	1	.....	2	4	.....	.....	1	4	30	.....	.....	.....
23	.....	.....	3	2	.....	.....	1	1	.....	1	.....	1	24	2	14	.....	.....	.....
24	.....	.....	6	1	.....	.....	1	1	.....	.....	.....	3	17	1	2	.....	.....	2
25	.....	.....	5	.....	.....	.....	.....	1	.....	.....	.....	6	13#	1	1	.....	3	5
26	.....	.....	9	1	.....	.....	.....	.....	.....	.....	.....	8	9	1	1	.....	8	22
27	.....	.....	13	.....	.....	.....	.....	3#	.....	.....	.....	8	1	.....	.....	.....	5#	19
28	.....	.....	12	.....	.....	.....	.....	.....	.....	.....	.....	5	1	.....	1	.....	3	9#
29	.....	1	22	.....	.....	.....	.....	5	.....	.....	.....	4	1	.....	.....	1	.....	5
30	.....	2	7	.....	.....	.....	.....	.....	.....	.....	.....	10#	4	.....	.....	1	.....	5
July 1	.....	7#	7	.....	.....	.....	.....	.....	.....	.....	.....	4	.....	.....	.....	4	1	1
2	.....	1	5	.....	.....	.....	.....	1	.....	.....	.....	8	.....	.....	.....	5	1	.....
3	.....	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	11	.....	1
4	.....	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	5	.....	.....	.....	15#	.....	1
5	.....	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	5	.....	.....	.....	9	.....	4
6	.....	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	11	.....	.....
7	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	.....	.....
8	1	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	4	.....	.....
9	2	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	3	.....	.....	.....	1	.....	.....
10	1	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....

Table 23. Dates of heading of parents, the F_2 generation and homozygous races from cross 14X—Continued
Parents: No. 4, Fulghum, C. I. 708; No. 15, Twentieth Century. The mean dates are indicated by#.

		1920			1921				1922				1923				1924			
		Parents			Parents		F_3 Families		Parents		F_4 from F_3 Families		Parents		F_4 from F_3 Families		Parent	F_4 from F_3 Families		
		No. 4	No. 15	F_2	No. 4	No. 15	1084	1105	No. 4	No. 15	1084	1105	No. 4	No. 15	1084	1105	No. 15	1084	1105	
July	11	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	12	2	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	
	13	2	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	
	15	#	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	16	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	19	1	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	20	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	22	.....	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	23	2	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	26	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	27	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Aug.	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	5	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	7	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Table 24. Mean dates of heading of parents and homozygous races from cross 14X

Parents: No. 4, Fulghum, C. I. 708; No. 15, Twentieth Century.

Year	Parents		Homozygous Races	
	No. 4	No. 15	1084	1105
1921	6/19.63± .38	6/18.32± .15	6/12.23± .15	6/14.20± .58
1922	6/26.92± .57	6/19.00± .21	6/16.00± .08	6/15.10± .06
1923	6/30.38± .34	6/24.58± .15	6/19.00± .10	6/19.79± .07
1924	.....	7/ 4.33± .17	6/26.90± .25	6/27.61± .20

Table 25. Dates of heading of parents, the F_2 generation and homozygous races from cross 44X—Continued

Parents: No. 20, Turkish Rustproof No. 3; No. 12, Sixty-Day. The mean dates are indicated by#.

		1920			1921				1922					1923			1924	
		Parents			Parents		F_3 Families		Parents On clay loam		Parents On clay		F_4 from F_3 Families	Parents		F_4 from F_3 Families	Parent	F_4 from F_3 Family
		No. 20	No. 12	F_2	No. 20	No. 12	497 551	577b	No. 20	No. 12	No. 20	No. 12	497 551 577b	No. 20	No. 12	551 577b	No. 12	551
July	11	....	....	5	....	....	....	....	....	....	....	....	 2	....	....	.... 8#	2	13
	12	....	....	2	....	....	....	....	....	....	....	....	.... 4#	....	....	 18	....	18
	13	....	....	5	....	....	....	....	....	....	....	....	 9	....	....	 1	....	20
	14	....	....	5	....	....	....	....	....	....	....	....	 10	....	....	 14	....	13
	15	....	....	2	....	....	....	....	....	....	....	....	 1	....	....	 5	....	6
	16	1	....	3	....	....	....	....	....	....	....	....	 5	....	....	 9	....	1
	17	....	....	4	....	....	....	....	....	....	....	....	....	....	....	 4	....	3
	18	....	....	3	....	....	....	....	....	....	....	....	 4	....	....	....	....	1
	19	....	....	8	....	....	....	....	....	....	....	....	....	....	....	 1	....	....
	20	....	....	8	....	....	....	....	....	....	....	....	....	....	....	 3	....	1
	21	....	....	1	....	....	....	....	....	....	....	....	 1	....	....	....	....	....
	22	....	....	3	....	....	....	....	....	....	....	....	 1	....	....	....	....	....
	23	....	....	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	24	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	25	....	....	1	....	....	....	....	....	....	....	....	....	....	....	 1	....	....
	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	 1	....	....
	27	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	28	....	....	....	....	....	....	....	....	....	....	....	 1	....	....	....	....	....
	29	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	 1	....	....
	31	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Aug.	1	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	5	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Table 26. Mean dates of heading of parents and homozygous races from cross 44X

Parents: No. 20, Turkish Rustproof No. 3, No. 12, Sixty-Day.

Year	Parents		Homozygous races		
	No. 20	No. 12	497	551	577b
1921	6/16.07± .27	6/18.67± .20	6/16.45± .16	6/14.37± .22	6/28.50± .69
1922 on clay loam	6/21.10± .31	6/19.88± .10	6/20.91± .10	6/20.72± .14	.....
1922 on clay	6/24.64± .60	6/23.40± .22	.....	.....	7/12.29± .41
1923	6/24.94± .08	6/23.93± .06	.....	6/23.15± .08	7/11.29± .26
1924	.....	7/ 9.14± .11	.....	7/ 9.17± .16	.....

Table 27. Dates of heading of parents, F_2 generation and homozygous races from cross 48X Parents: No. 21, Turkish Rustproof No. 4; No. 12, Sixty-Day. The mean dates are indicated by#.

		1920			1921				1922						1923				1924			
		Parents			Parents		F_3 Families		Parents				F_4 from F_3 Families		Parents		F_4 from F_3 Families		Parent	F_4 from F_3 Families		
									On clay loam		On clay											
		No. 21	No. 12	F_2	No. 21	No. 12	947	957	No. 21	No. 12	No. 21	No. 12	947	957	No. 21	No. 12	947	957	No. 12	947	957	
June	15	....	....	....	....	....	....	....	....	....	....	....	On	....	....	....	....	....	....	....	....	
	16	....	....	....	....	1	....	....	....	....	....	....	clay	....	....	....	....	....	....	....	....	
	17	....	....	....	....	3	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	
	18	....	....	....	....	5	4	8	....	2	....	....	1	4	....	....	....	....	....	....	....	
	19	....	....	....	....	7#	3#	2#	....	6	....	....	....	1	....	....	....	....	....	....	....	
	20	....	....	....	....	4	11	5	....	9#	....	....	1	9	....	....	....	....	....	....	....	
	21	....	....	....	....	....	1	5	....	1	....	3	4	15	....	....	....	....	....	....	....	
	22	....	....	....	....	1	1	....	....	2	....	3	3	12	....	4	....	....	....	....	....	
	23	....	....	....	....	....	....	1	....	....	....	4#	9	28	....	44	4	12	....	....	....	
	24	....	....	1	....	....	....	....	....	....	....	1	14	32	....	41#	31	37	....	....	....	
	25	....	....	....	....	....	....	....	....	....	....	....	30	35	....	25	73	76	....	....	....	
	26	....	....	2	....	....	....	....	....	....	....	2	32	29#	....	6	62	32#	....	....	....	
	27	....	....	1	....	....	....	....	....	....	....	....	24#	28	....	2	40#	18		....	....	
	28	....	....	10	....	....	....	....	....	....	....	....	51	78	....	....	27	15	....	....	....	
	29	....	10	6	....	....	....	....	....	....	....	....	47	45	....	....	7	2	....	....	....	
	30	....	32	8	....	....	....	....	....	....	....	....	9	5	....	....	10	10	....	....	....	
July	1	....	10#	12	....	....	....	....	....	....	....	....	22	11	....	....	2	3	....	....	....	
	2	....	9	5	....	....	....	....	....	....	....	....	....	....	....	....	4	4	1	....	....	
	3	....	5	5	....	....	....	....	....	....	....	....	....	....	....	....	....	1	5	....	....	
	4	....	....	4	....	....	....	....	....	....	....	....	....	....	....	....	1	3	21	....	1	
	5	....	4	4	....	....	....	....	....	....	....	....	....	....	....	....	3	2	10#	....	1	
	6	....	1	2	....	....	....	....	....	....	....	....	....	....	....	....	1	....	5	....	....	
	7	....	1	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	3	
	8	....	....	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	5	4	
	9	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	2	....	2	2	1#	
	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	7#	3	
	11	....	....	1	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	1	
	12	....	....	....	#	....	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....	
	13	....	....	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	
	14	....	....	2	5	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	
	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	
	16	....	....	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	19	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	20	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	21	....	....	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	22	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	24	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	28	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	

Table 27. Dates of heading of parents, F_2 generation and homozygous races from cross 48X—Continued
Parents: No. 21, Turkish Rustproof No. 4; No. 12, Sixty-Day. The mean dates are indicated by#.

	1920			1921				1922					1923				1924		
	Parents			Parents		F_3 Families		Parents on clay loam		Parents on clay		F_4 from F_3 Families	Parents		F_4 from F_3 Families		Parent	F_4 from F_3 Families	
	No. 21	No. 12	F_2	No. 21	No. 12	947	957	No. 21	No. 12	No. 21	No. 12	947 957	No. 21	No. 12	947	957	No. 12	947	957
July 30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
31	....	....	1	....	....	....	....	1	....	1	....	....	....	....	....	....	....	....	....
Aug. 1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	....	....	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....
3	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....
6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	2	....	....	....	....	....	....	....	....	#	....	....	....	....	....	....	....	....	....
8	1	....	....	....	....	....	....	1#	....	....	....	....	....	....	....	....	....	....	....
9	1	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
12	1	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
14	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	3	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....
16	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
17	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
18	2	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
19	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	#	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
22	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
26	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
29	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sept. 1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
6	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Did not head	7	....	9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Table 28. Mean dates of heading of parents and homozygous races of cross 48X
Parents: No. 21, Turkish Rustproof No. 4; No. 12, Sixty-Day.

Year	Parents		Homozygous races	
	No. 21	No. 12	947	957
1921	7/12.19± .53	6/18.67± .20	6/19.26± .24	6/19.45± .24
1922 on clay loam	8/ 7.89±1.63	6/19.75± .16	.....	6/25.98± .09
1922 on clay	8/ 6.67±1.72	6/22.85± .30	6/27.14± .10	.....
1923	.....	6/23.93± .06	6/26.56± .12	6/26.06± .12
1924	.....	7/ 4.77± .16	7/ 9.84± .18	7/ 8.75± .45

THE QUANTITATIVE EFFECT OF THE FACTORS

One object of this study was to determine the quantitative effect of the factors. It has been shown that the influence of the factors upon time of heading varied with the different seasons, probably with the different parts of the same season, and also with variations in the soil. It has not been satisfactorily proved that these factors have the same effect, but if we compare the homozygous races recovered with the early parents in the crosses it seems as if they may have the same or approximately the same effect and that each caused an average difference of two to two and one-half days in time of heading in the three years 1921 to 1923.

In Table 30, the homozygous races are compared with their early parents in time of heading and arranged in order of earliness. In most cases the parents were grown with the homozygous families so that there would be the least influence due to soil differences. The parents were also grown together in one or more places in the area for comparison with each other.

These early parents headed together, as shown in Table 29, and so direct comparisons may be made of the differences between these homozygous races and their respective parents. Incidentally, it is of interest that these five varieties seem also identical in their factors for earliness, for seven crosses were made between pairs of these varieties which include all of them and in every cross the F_1 plants headed with the parents. Of one cross: Namely, No, 12 x No. 15, the F_2 generation was grown and it headed also with the parents. The crosses made were as follows: No. 1 x No. 2, No. 1 x No. 12, No. 1 x No. 15, No. 2 x No. 12, No. 2 x No. 15, No. 12 x No. 3, and No. 12 x No. 15.

It may be that in this series the factors have the same effect and that the first two races are earlier than the early parents by three factors and the next four earlier by two factors Races 48, 551, and 497 do not agree with this scheme, however, unless we make generous allowance for variations due to soil differences, to changes in weather conditions, or to inadequate numbers. In 1921 the members were small, only 23 plants of family 48, only 16 of family 551, and 18 of family 497. Because of the inconsistency of race 551 with respect to time of heading, the F_4 generation was grown again in 1924 and then the difference between this race and the early parent grown beside it was .03 ± .19.

Races 96, 947, and 957 seem to be later than the early parents by one factor, race 80 later by two factors, and race 577b by probably five factors.

A good many crosses have been made between the races and varieties showing only small differences in time of heading, and if any of these prove to be monohybrids the quantitative effects of the factors involved can be determined.

Table 29. Mean dates of heading of the five early varieties used in the crosses studied to show that they headed approximately together every year

Varieties	Mean dates of heading				
	1920	1921	1922	1923	1924
No. 1, Richland, C. I. 787	6/30.14± .10	6/18.08± .10	6/22.33± .51	6/25.05± .25	7/5.43± .13
No. 2, Albion, C. I. 729..	6/30.26± .18	6/18.62± .15	6/21.94± .33	6/24.33± .15	7/5.15± .10
No. 3, Kherson, C. I. 134.	6/30.71± .08	6/18.41± .07	6/21.80± .19	6/28.00± .52	7/7.07± .16
No. 12, Sixty-Day.....	6/30.84± .13	6/18.50± .12	6/22.85± .30	6/24.38± .14	7/4.77± .16
No. 15, Twentieth Century	7/ 1.13± .12	6/18.32± .15	6/22.64± .52	.....	7/4.74± .14

Table 30. Homozygous races compared with their respective early parents in mean dates of heading in order of date of heading

Races	Cross	Early parent	Days earlier than early parents			
			1921	1922	1923	Mean
1049	4X	Ho. 2	8.09± .23	6.38± .18	5.46± .20	6.64± .20
1058	4X	No. 2	7.24± .25	6.13± .24	4.56± .19	6.31± .23
1084	14X	No. 15	6.09± .21	3.00± .22	5.58± .18	4.89± .20
1052	4X	No. 2	5.96± .20	3.96± .17	3.96± .18	4.63± .18
1105	14X	No. 15	4.43± .55	3.90± .22	4.79± .17	4.37± .36
45	10X	No. 3	4.76± .21	3.26± .20	4.53± .14	4.14± .19
48	10X	No. 3	4.47± .17	1.06± .20	3.37± .13	3.30± .17
551	44X	No. 12	4.30± .30	−.84± .17	.78± .10	1.41± .21
497	44X	No. 12	2.22± .26	−1.03± .14	.....	.....
96	10X	No. 3	−1.57± .20	−4.80± .29	−.75± .14	−2.37± .22
947	48X	No. 12	−.59± .31	−4.29± .32	−2.63± .13	−2.50± .27
957	48X	No. 12	−.78± .31	−6.23± .18	−2.13± .13	−3.05± .22
80	10X	No. 3	−2.43± .26	−8.79± .20	−5.85± .22	−5.69± .23
577b	44X	No. 12	−9.83± .72	−18.89± .47	−17.36± .27	−15.36± .52

SOME PLANTS IN ONE CROSS FAIL TO HEAD

In the cross 48X, No. 21 x No. 12 (Turkish Red Rustproof No. 4 x Sixty-Day) nine plants out of 90 failed to head in the F_2 generation, and in the F_3 generation there were 29 families out of 73 grown which had some plants which did not head. Some of these families began heading about the middle of June and continued until late in August or until September and then had a few plants which did not head. These doubtless were from very complex hybrids.

The plants which failed to head were not of the winter type as has been reported in crosses between spring and winter varieties of wheat, for they jointed late in August. Fig. 1 shows three such plants.

In October, 1921, eight such plants were potted and removed to a greenhouse. Of these two died and the others headed from March 28 to June 6. The earliest of these bore four seeds, all of which produced vigorous plants which jointed late in the summer but did not head. The others did not produce any viable seed. These plants which did not head seem to have been the lowest recessive in the cross rather than the result of a segregation into spring and winter forms.

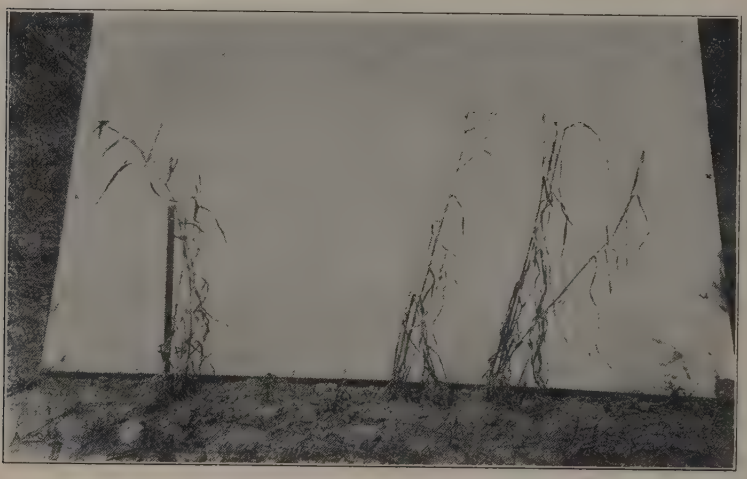


Fig. 1. Three plants from Cross 48X, typical of those which jointed late but failed to head. These grown in the field in 1922 and photographed September 8.

SUMMARY

In this study of earliness in oats, there are reported (counting duplicate and reciprocal crosses but once) F_1 generations of 23 crosses, F_2 generations of 22 crosses and F_3 and F_4 generations of five crosses.

The F_1 plants of crosses between parents unlike in earliness headed at the same time as the early parent or earlier, with the exception of three crosses: namely, 39X, 44X, and 48X, in which they were a little later than the early parents but much earlier than the late (See Diagram 1 and Table 9). The F_1 generations of these crosses were grown in the greenhouse where the fluctuating variability was very great. Of these crosses the F_2 generations began heading earlier than

the early parent, indicating in the light of the results from the other crosses that these F_1 plants were potentially as early as the early parent or earlier.

In one cross, 51X, the parents headed together but the F_1 was much earlier than the parents and of the F_2 generation 41 plants out of a total of 45 were earlier than the earliest plant of the parents. (See Tables 10 and 16).

With few exceptions, which seem to have been due to fluctuating variability, in the crosses of which the F_1 plants headed at the same time as the early parents, the F_2 plants began heading with the early parents; and in the crosses in which the F_1 plants headed earlier than the early parents, the F_2 plants began heading earlier than the early parents.

The modes for the dates of heading of the F_2 populations in crosses in which the parents were unlike in earliness in most cases approximately coincided with the modes of the early parents; the mode in the cross in which the parents were alike in earliness was much earlier than that of the parents.

Homozygous races were recovered from five crosses by growing F_3 generations and then F_4 generations from those families which seemed homozygous. The homozygous races recovered included those earlier than the early parents, like the early parents, intermediate between the parents, and later than the late parents.

The data seem to prove that earliness in these crosses was due to a series of dominant factors which together had a cumulative effect. In the crosses in which the F_1 plants headed with the early parents and the F_2 plants began heading with the early parents, the early parents have one or more dominant factors which the late ones lack. In the crosses in which the F_1 plants were earlier than the early parents and the F_2 began heading earlier than the early parents, each parent seems to have one or more dominant factors which the other lacks. (See page .) This second condition applies also to the cross in which the parents headed together but gave early F_1 plants and an F_2 population which began to head earlier than the parents.

The data do not prove conclusively that the factors have the same effect, but it seems as if they may have, and that each factor caused an average difference in earliness of from two to two and a half days in 1921 to 1923. It is hoped that some crosses made later between races and varieties which differ in heading by only short intervals will prove to be monohybrid crosses and the quantitative effects of some factors can with more certainty be determined from them.

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